SYSTEMS

Introduction

DOE-2 requires a fair amount of understanding of how systems operate. A general description of types of systems is given in this manual. Once you have understood the structure used for the LOADS input, there should be little difficulty in learning the procedure for assembling a SYSTEMS input. The major problem most users have is that DOE-2 offers a high degree of flexibility and a large choice of options for SYSTEMS input. To use this flexibility wisely you are required to know more about HVAC systems than was required by previous energy analysis programs. In the earlier programs, you could simply assign the *name* of the desired system and the program would pull from its file all of the necessary input. To a degree this can be done with DOE-2 by relying on default values and prestored control methods. However, this is not the recommended procedure and is an option to be used only until the you feel comfortable with explicitly specifying the many commands and keywords in DOE-2.

General Discussion of Systems

In this subsection we describe the general properties of HVAC systems for users whose knowledge in this area is limited. *It is important to know what various systems do and not simply know their names.* We will stress the common features and heritage of various systems rather than concentrating on their differences.

Generally, air systems can be split into five distinct categories:

1. Variable Air Temperature Systems (Constant Volume)
2. Reheat Systems (Constant Volume)
3. Air Mixing Systems (Constant Volume)
4. Variable Air Volume Systems (Constant Temperature)
5. Hybrid Systems - A mixture of Systems 1 through 4

Variable Air Temperature Systems (Constant Volume) (SZRH, PSZ)*

Variable air temperature systems are totally responsive to the master control zone's sensible heat gains and losses. As heat gains decrease, the temperature of the supply air increases proportionately, and vice-versa. Usually the heating coil is placed in front of the cooling coil for freeze protection and the two coils are controlled in sequence by the space thermostat. The single zone system is representative of this type of system, with the added feature that subzone reheat coils can be used to adjust for the heating requirements of the subzones that differ from that of the first named zone (in the list of zones assigned to the system).

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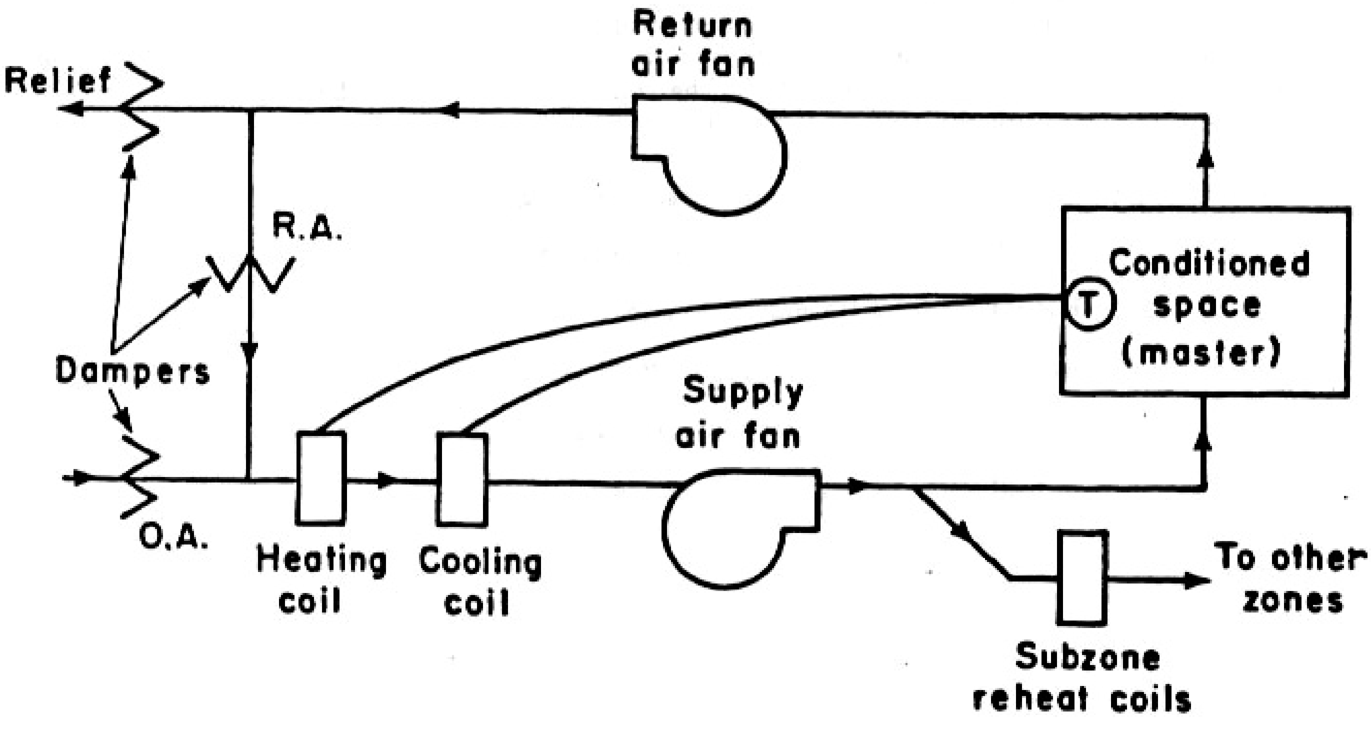

Figure 3.1: Variable Air Temperature System

* The corresponding DOE-2 SYSTEM-TYPE code-words are given in parentheses; for example, PSZ is the DOE-2 "packaged single zone" system. See p.3.8 for a list of system types and code-words.

Reheat Systems (Constant Volume) (RHFS)

Reheat Systems were a natural outgrowth of the single zone variable air temperature system; the reheating coil is located downstream of the cooling coil so that all supply air is cooled as well as dehumidified (the supply air is maintained at a constant temperature). This makes the cooling energy use unresponsive to space loads, whereas the reheat is responsive to space loads, but inversely so. For example, when space heat gains are at their maximum, reheating is not required to hold space temperatures. However, as space heat gains decrease, reheating must increase to compensate for the disappearing space heat gains. Under all conditions the cooling coil cools the air to a constant temperature fixed for the maximum anticipated loading. This is, therefore, an energy intensive system.

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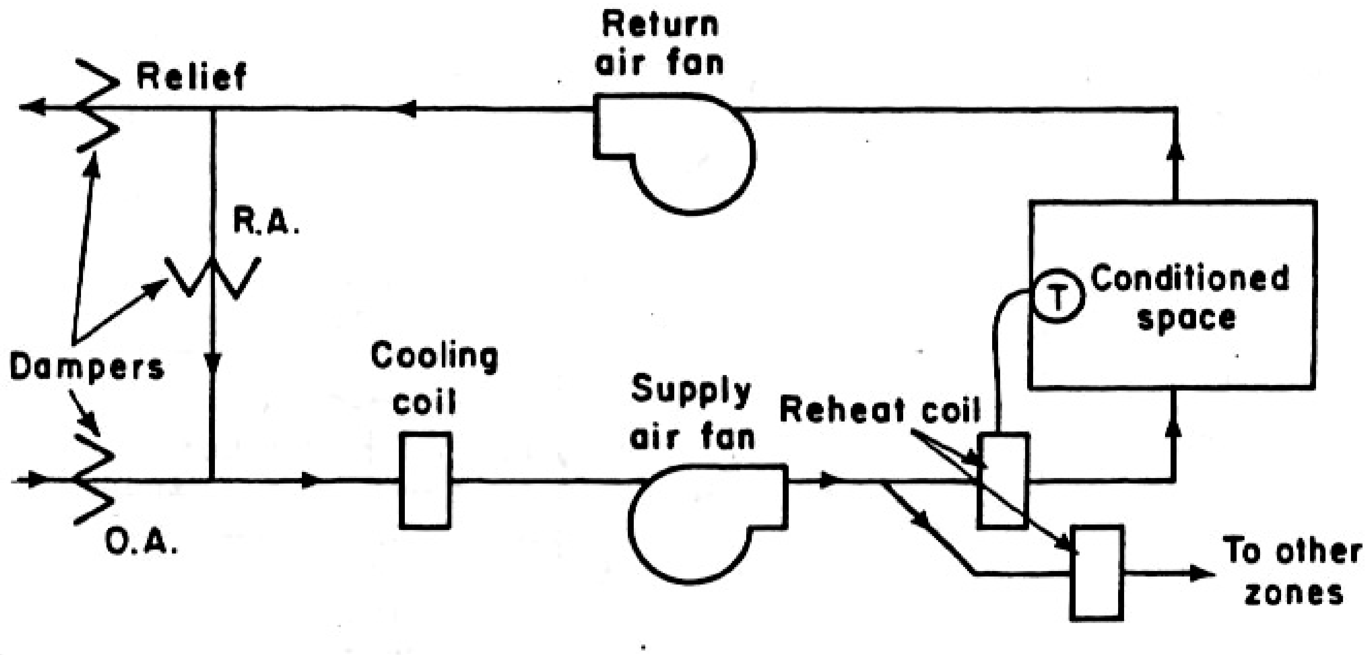

Figure 3.2: Reheat System

Air Mixing Systems (Constant Volume) (DDS, MZS, PMZS)
These systems are commonly referred to as Dual Duct and Multi-Zone Systems. They control space temperatures by the mixing of two air streams, one of which is normally above the space temperature and the other normally below the space temperature. In this constant volume configuration they are also energy intensive.

To understand why air mixing systems can be large energy users, it is necessary to understand the effect the hot deck temperature has on the systems energy consumption during cooling periods. Given a space that requires partial cooling, a given quantity of cold air is needed to satisfy the load; however, the excess air that is not used to satisfy the load must still go to the space because the system is constant volume.

It follows that, of the total supply air that remains in excess of that required to satisfy the space load, the hot stream and the cold stream must mix thermally to cancel each other. If the cold deck is 55°F, the space temperature 75°F, and the hot deck 95°F, the two air streams will mix in equal parts to cancel each other.

However, if the hot deck is 155°F and all other criteria remain unchanged, then the cold deck will pass 4 parts, and the hot deck 1 part, to cancel each other. The cooling and heating energy expended on the excess air for these two hypothetical cases is 1.6 times as much for the second case as for the first. Reset of hot and cold deck temperatures to minimize temperature difference between the hot and cold decks will minimize energy consumption on these systems.

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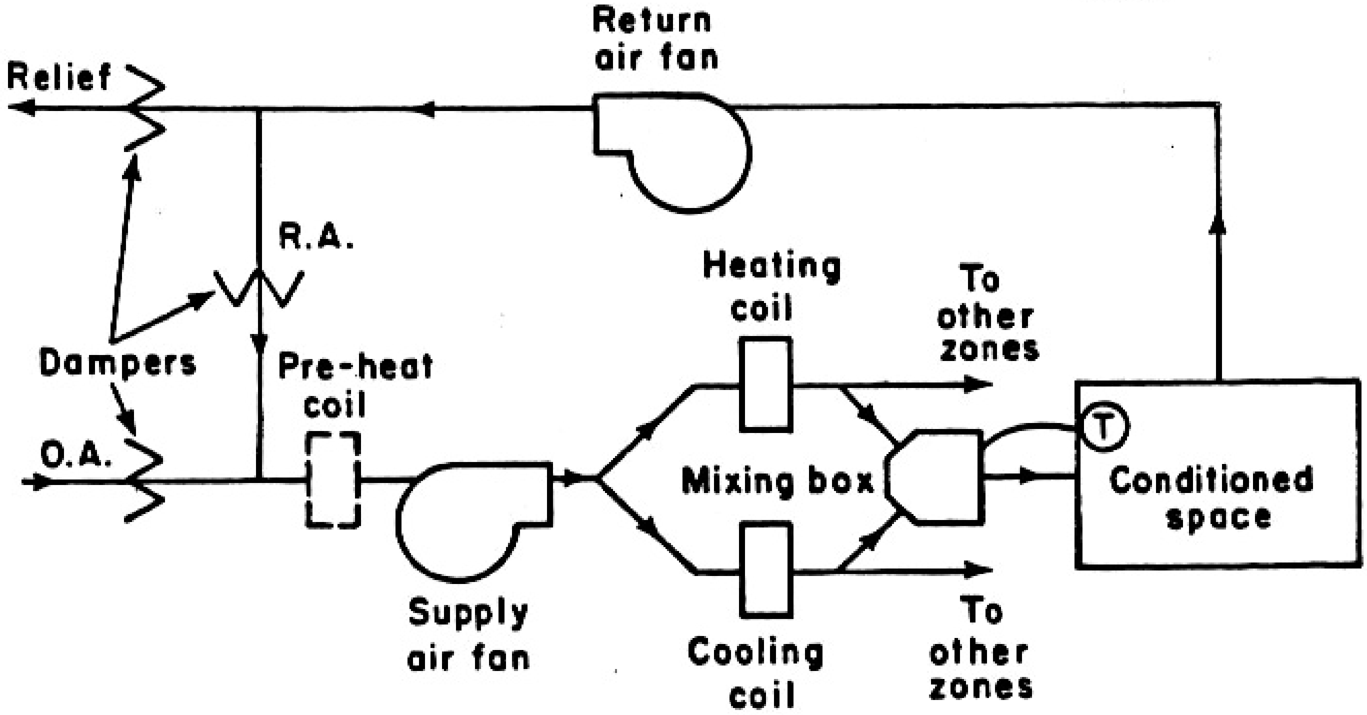

Figure 3.3: Air Mixing (Constant Volume) Systems

Variable Air Volume (Constant Temperature) Systems (VAVS, PVAVS)
Variable Air Volume systems are the easiest to understand. With a decreasing heat gain in the space, the system responds directly with a corresponding decrease in (cold) air supply to the space. Most systems have a minimum stop beyond which the air supply is no longer decreased. The ratio of this minimum air-flow-rate to the design air-flow-rate is referred to as MIN-CFM-RATIO. If an interior space is occupied, the heat gain from lights and people will require sufficient air flow to remove the load; however, in perimeter spaces the heat losses may offset the heat gains from lights and people, resulting in a load that is close to zero. Then it is necessary to set the MIN-CFM-RATIO to provide sufficient ventilation air; either reheat or baseboard radiation is used to offset the cooling effect of the minimum allowable air supply and to supply heat to offset the heat losses.

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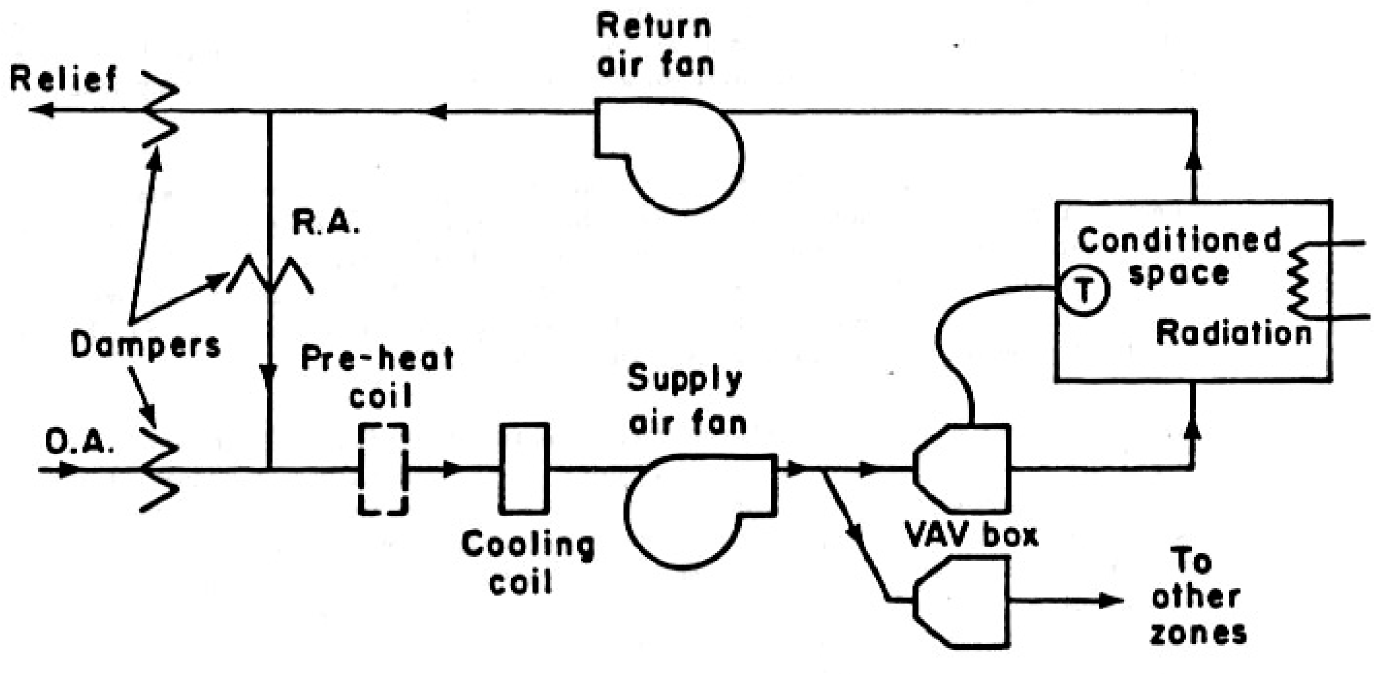

Figure 3.4: Variable Air Volume (Constant Temperature) Systems

Hybrid Systems

a. Hybrid Systems are defined here as a combination of any of the first four systems described. For example, we have VAV–Reheat Systems with a minimum stop on the supply box specified by MIN–CFM–RATIO. Typically, this system acts as a VAV system if the total air supply is above the MIN–CFM–RATIO setting. Whenever the system supply air needed is less than that allowed by the MIN–CFM–RATIO, the system conforms to a standard reheat system.

b. Another form of Hybrid System is the VAV–Dual Duct System. Again, only when the total supply air requirement is less than that allowed by the MIN–CFM–RATIO, does the system act as a typical dual duct system which mixes two air streams to satisfy the space thermostat.

c. Powered Induction Units (PIU) are a variation of the VAV system with the addition of a small fan to pull air from the ceiling plenum and mix it with air supplied from the central system.

Other System Types in DOE-2

a. Fan Coil (TPFC and FPFC). Fan Coil Units are either 4-pipe or 2-pipe. The 4-pipe units usually have two coils (one heating and one cooling), but may have one dual purpose coil. The units modulate the flow of water to the coil(s); this conforms to a variable air temperature system. Outside air for fan coil systems is usually introduced by a separate ventilation system; however, outside air may be introduced directly into the fan coil unit.

b. Packaged Units (PSZ, PMZS, PVAVS, and PTAC). These systems are similar, schematically, to the systems already described except that they are usually unitary (fans, compressors and condensers are physically cased in a single unit). In DOE-2 they perform cooling with direct expansion coils, which require data about ambient wet and dry bulb temperatures. As a result, the entire cooling calculation is done in SYSTEMS and only the resulting electrical load is passed to PLANT.

c. Incremental Heat Pump (HP). Also referred to as the Water Source Heat Pump, Water Loop Heat Pump, or Water/Air Heat Pump. These systems are composed of small self-contained cooling/heating units connected to a common water loop. Units on cooling reject heat to the circuit; units on heating draw heat from this source and pump it up to a higher level. A hot water generator is a supplemental heat source when the majority of units are heating. An evaporative cooler (closed circuit cooling tower) is used to reject heat to the atmosphere when the majority of units are cooling. These latter must be input in PLANT.

d. Residential System (RESYS). It is possible to simulate the following combinations of systems, appropriate to a residential building modeled as a single zone. Cooling may be accomplished with an air-cooled electric-driven air conditioner; heating may be provided by a forced-air furnace, electric resistance air coil, or hot water baseboards. Alternatively, both heating and cooling can be supplied by an air-to-air heat pump with supplemental electric resistance heating.

e. Heating Only Systems. DOE-2 can simulate a number of heating-only systems. They are:

   i. Unit Heaters (UHT)
   ii. Unit Ventilators (UVT)
   iii. Baseboard Radiators

   UHT and UVT heating-only units are described later in detail. They are especially useful in analyzing buildings constructed before air conditioning became popular.

   Baseboard radiators can only be simulated in combination with the air systems. You must specify a value for the keyword BASEBOARD–RATING (the heating capacity of the baseboards in Btu/hr). In addition, you must specify the kind of BASEBOARD–CONTROL, either OUTDOOR–RESET (the default) or THERMOSTATIC.

f. Recovery Systems. The DOE-2 program allows you to simulate either a coil run-around heat recovery cycle or a heat wheel. The heating effect due to heat exchange between return air and colder outside air is the only configuration available. (The **cooling** effect due to heat exchange between return air and **warmer** outside air cannot be simulated.)

Specific HVAC Distribution Systems

The SYSTEMS program simulates the heat and moisture exchange processes that occur in secondary HVAC distribution systems. Likewise, it simulates the performance of air circulating fans used in these systems. You select appropriate systems (plus options) from a list of 16 different standard or familiar types of systems. There are an additional 10 system types that are used less commonly or are very difficult for a new user to input; see the *Reference Manual (2.1A)* and/or the *Supplement (2.1E)*. The SYSTEMS subprogram cannot simulate two different types of air systems in one zone at the same time. For example, it is not possible to simulate the cooling of a zone by both a Single Zone Fan System (SZRH) and a Two Pipe Fan Coil System (TPFC).

System types in DOE-2 have been categorized into different generic types, built-up systems vs. packaged systems and central systems vs. zonal systems.

Built-Up Systems

Depending upon the system types chosen, ***built-up systems*** contain preheat coils, main heating coils, cooling coils, zone (reheat) coils, baseboard heaters, fans (supply, return, and exhaust), thermostats, humidifiers, dehumidifiers, economizers, outside air dampers, mixing dampers, throttling dampers, and air ducting. However, built-up systems are **not** usually self-contained; the central equipment (i.e., boilers, chillers, cooling towers, pumps, etc.) that produces hot or chilled water and electrical energy is separated from the distribution system. That equipment is simulated in DOE-2's PLANT subprogram. Built-up system simulations result in demands that are passed to PLANT, for hot water, chilled water, electricity, gas, and/or oil. These demands may be met in PLANT by purchased utilities or energy conversion equipment.

Packaged Systems

Packaged systems are usually self-contained units. These units are usually produced as one or more modular pieces of prematched equipment that only require installation. They possess all the necessary equipment for energy conversion and distribution and they, too, produce a utility demand for electricity, gas, and/or oil.

Zonal vs. Central Systems

Reference is sometimes made to a *zonal system*, defined herein to mean any system with an air-handling unit in each zone and controlled by a thermostat in that zone. It may be a packaged self-contained system (fueled only by a utility) or it may be supported by a *central system* (supplying hot water, chilled water, warm air, or cool air). Zonal systems are UHT, UVT, TPFC, FPFC, HP, and PTAC.

The DOE-2 systems listed below are described in the following pages of this section.

SZRH	Variable temperature constant volume air-handling unit
RHFS	Reheat constant volume air-handling unit
MZS	Multizone constant volume air-handling unit
DDS	Dual duct constant volume or variable volume air-handling unit
VAVS	Variable volume air-handling unit
PIU	Powered Induction unit variable air volume air-handling unit
TPFC	Two pipe fan coil
FPFC	Four pipe fan coil
RESYS	Residential furnace and packaged condensing unit/heat pump
PSZ	Packaged single zone variable temperature DX unit
PMZS	Packaged multizone DX unit
PVAVS	Packaged variable volume DX unit
PTAC	Packaged terminal air conditioner/heat pump
PTGSD	Packaged total gas solid desiccant
UHT	Unit heater
UVT	Unit ventilator (heat only)

Other available systems that are not described here are the following. See the *Supplement (2.1E)* for details on these systems.

EVAP-COOL	Evaporative cooling unit
PVVT	Packaged variable-volume, variable-temperature unit
RESVVT	Residential variable-volume, variable-temperature unit
HP	Water source heat pumps connected to a common water loop
CBVAV	Ceiling bypass unit
TPIU	Two pipe induction unit
FPIU	Four pipe induction unit
SZCI	Ceiling induction unit
HVSYS	Heating and ventilating system
FPIU	Four pipe induction unit

In the material that follows, you will find

1) A full description of each system type, including a schematic of the system showing the location of fans, heating and cooling coils, ductwork and control devices.

2) For each system type, a suggested input that provides a no-frills simulation of that system. Square-bracketed numbers in this input are keyed to the bracketed numbers in the system schematic. A compatible PLANT input is also given. This input is compatible with the example on p.1.9 and therefore could be used to replace the example's SYSTEMS and PLANT input and thus build a new input file.

3) For each system type, a list of other capabilities that can be simulated, with pointers showing where you can find an example or a more complete description. Again, square-bracketed numbers are keyed to the bracketed numbers in the system schematic.

Single-Zone Fan System with Optional Subzone Reheat (SZRH)
In its most basic configuration SZRH provides constant volume, forced-air heating and cooling for a single zone (plus subzones) from an air-handling unit containing a heating coil, cooling coil, filters (not shown), and supply fan. Exhaust fans are optional for any or all zones. The temperature of discharge air is controlled from a thermostat that senses space conditions in the control zone. This zone is specified as the first zone entered under the keyword ZONE–NAMES. The system may be small and located within the space to be conditioned, or may be remotely located with ducted air distribution. It may provide outside air ventilation, or merely recirculate conditioned air.

Note: On the schematic, items shown in dashed boxes are optional components.

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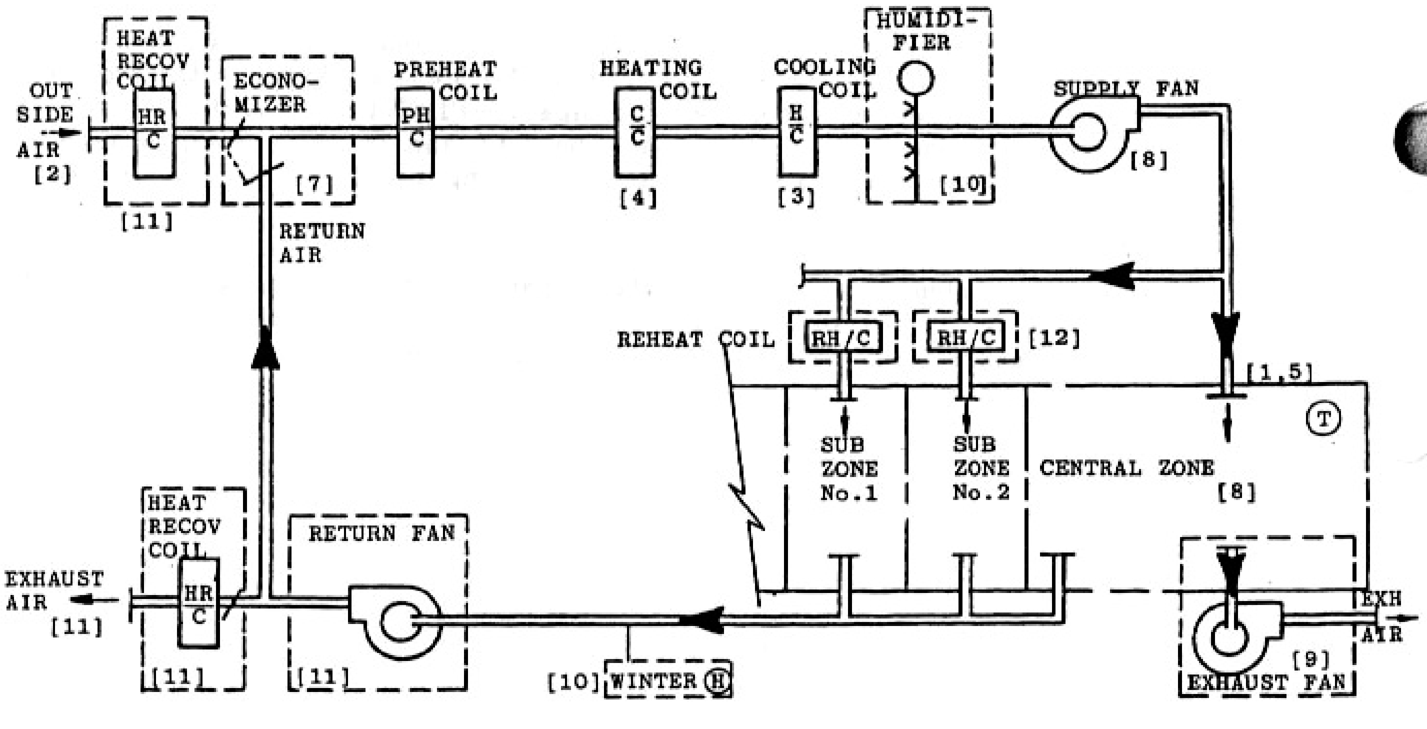

Figure 3.5: Single-Zone Fan System with Optional Subzone Reheat